Observing and modelling Earth's albedo and its interhemispheric symmetry

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Earth Radiation Budget Worskhop, Oct 13 2022

Bolin Centre for Climate Research

Why albedo?

visibleearth.nasa.gov

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- $S_0/4(1- \alpha)=\sigma T^4$

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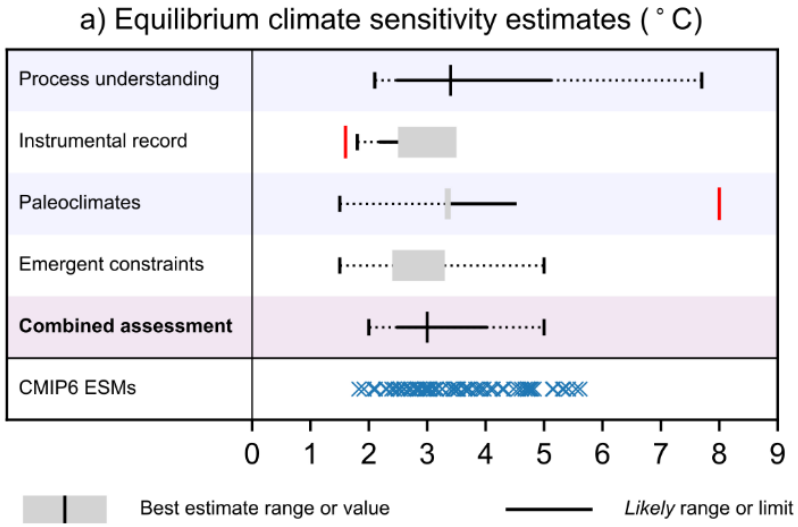
- $\alpha = f(\text{cloud})$
- $\alpha(\text{NH}) \approx \alpha(\text{SH})$

visibleearth.nasa.gov

Why care about cloud representation in global models?



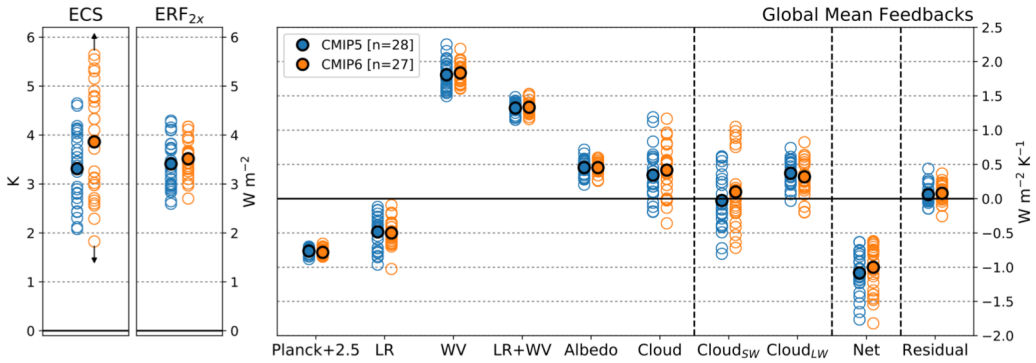
IPCC AR6 Fig 7.18 (cropped)

-Multiple lines of evidence narrows ECS uncertianty range in AR6

-ECS best estimate 3C and *very likely* range 2C to 5C

-Cloud feedback dominant source of uncertainty in future projections

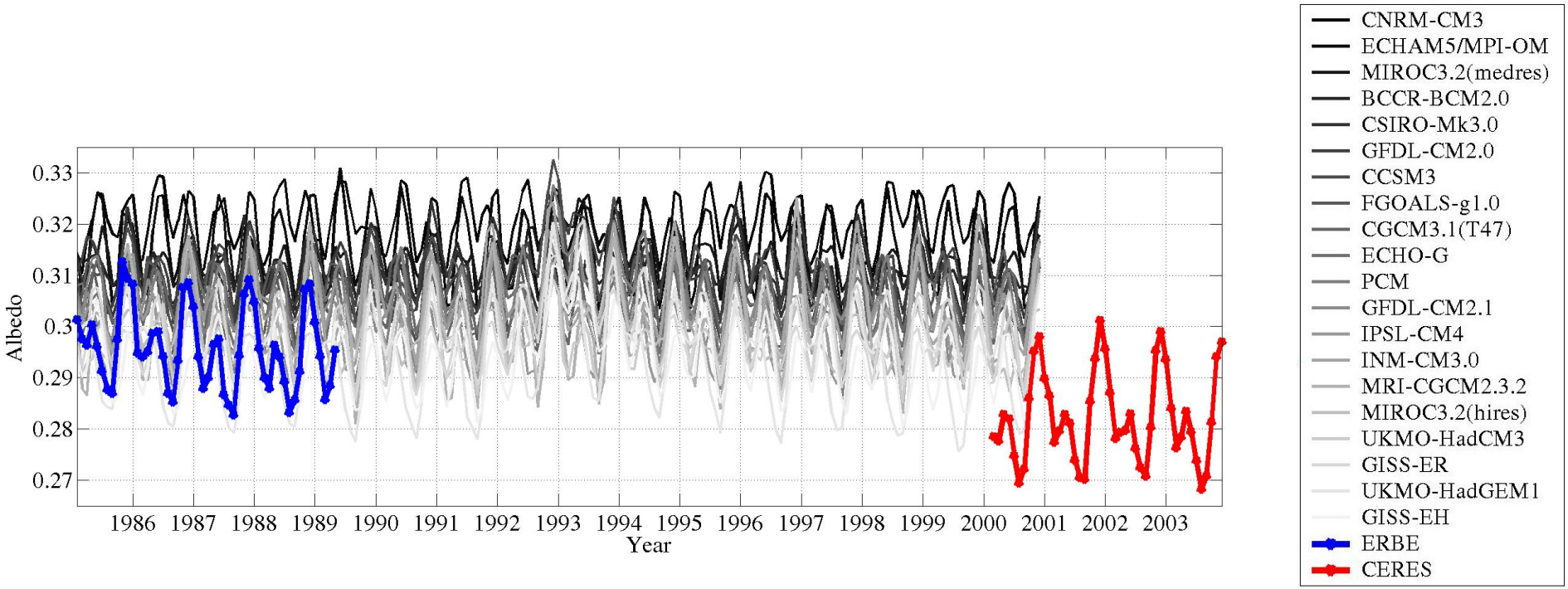
Cloud feedback in CMIP5 and CMIP6



- More positive cloud feedback in CMIP6 than in CMIP5 explains higher sensitivity

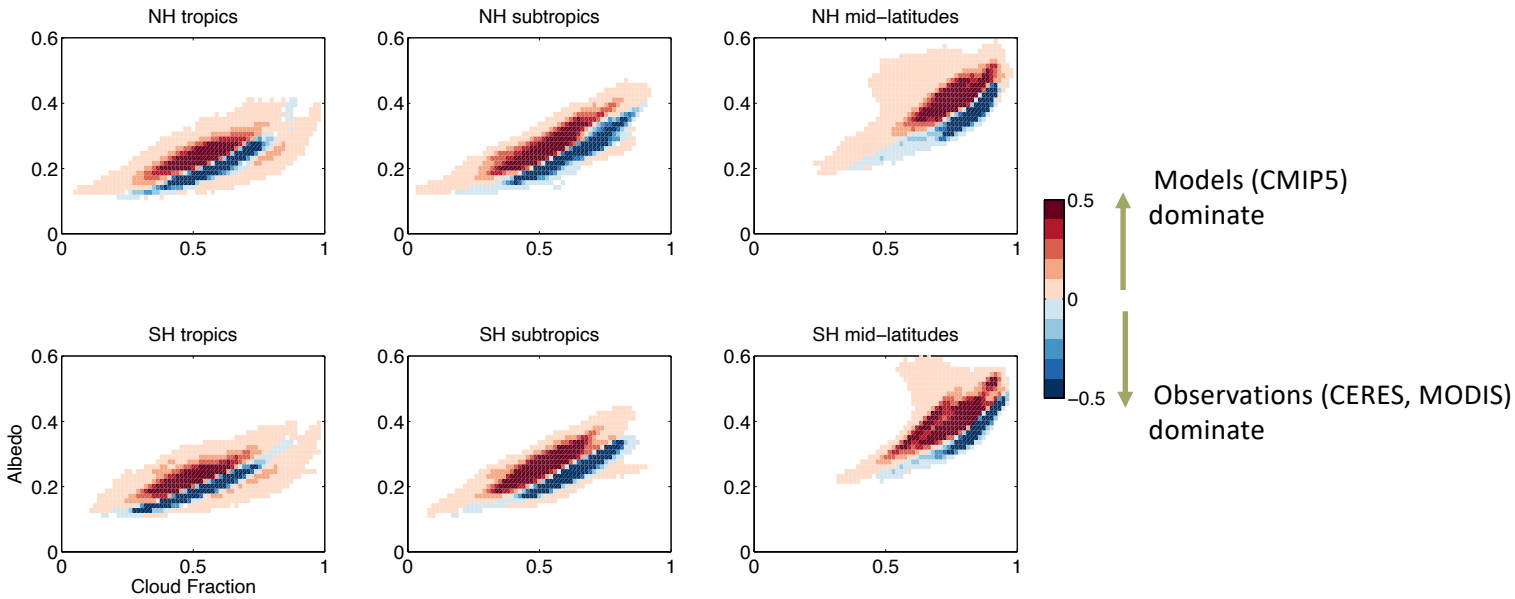
Zelinka et al (2020), GRL

Global albedo – CMIP3



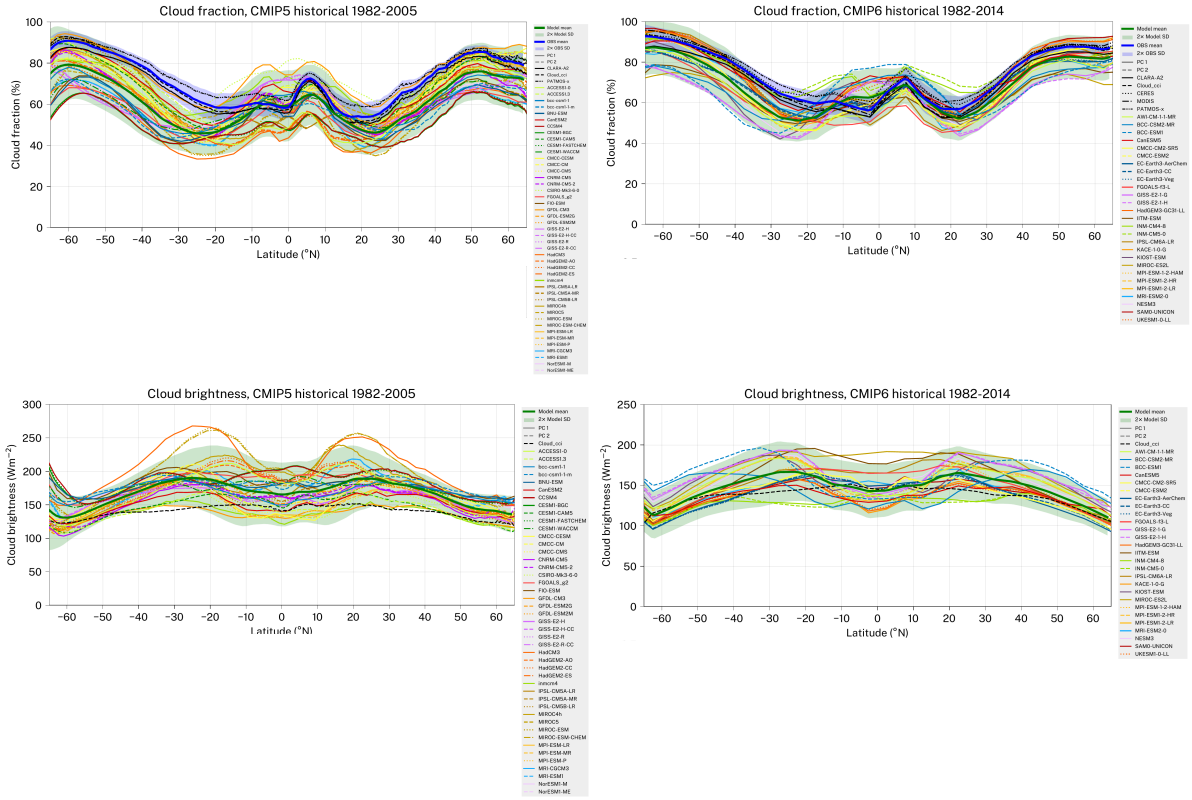
Bender et al (2006), Tellus

Model clouds overall ”Too few, too bright”



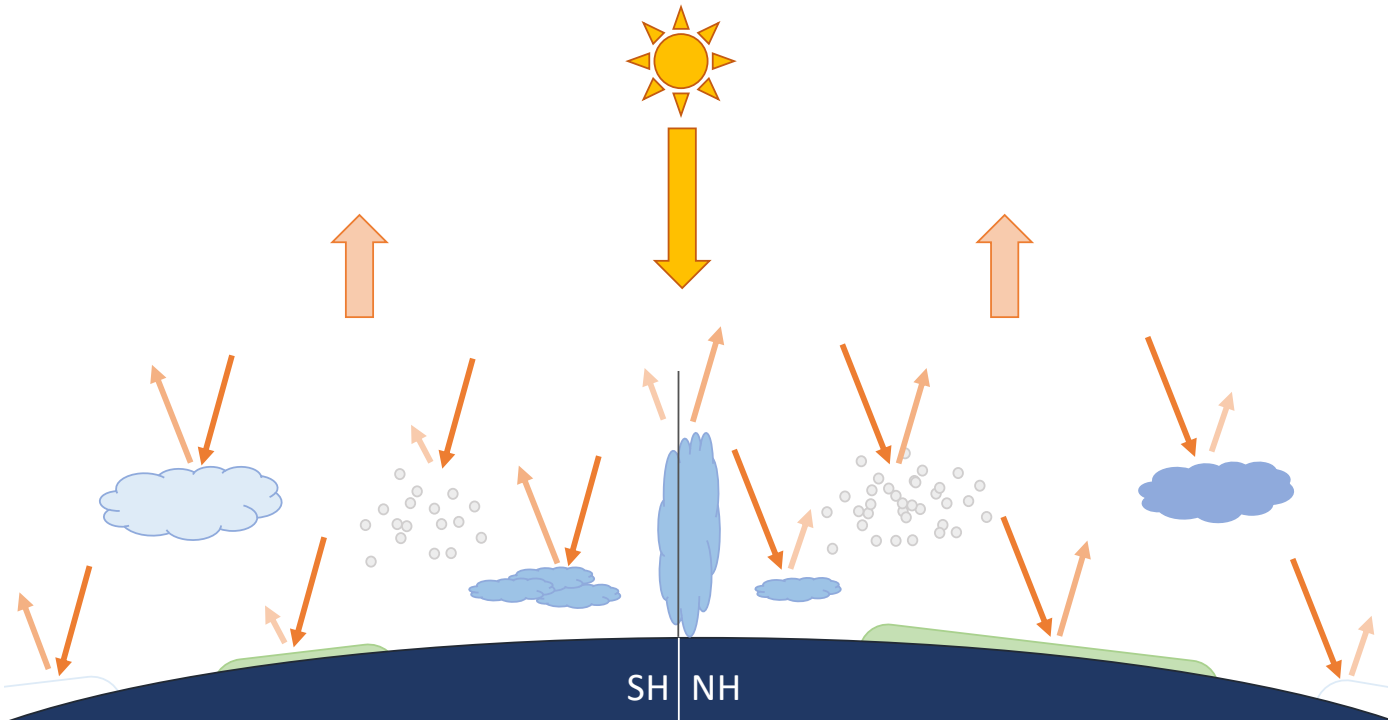
Bender et al (2017), J Clim

”Too few, too bright” remains in CMIP6



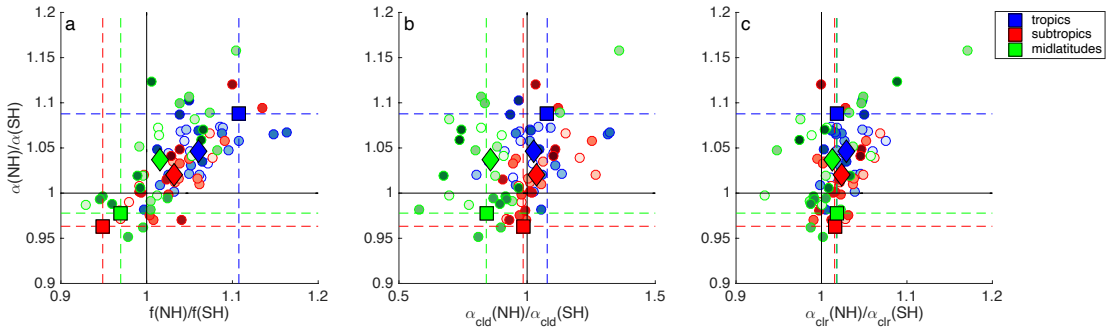
Courtesy Peter Kuma

Interhemispheric albedo symmetry



E.g. Voigt et al. (2013, 2014), Stephens et al. (2015), Bender et al. (2017), Datseris & Stevens (2021), Jönsson & Bender (2022), Diamond et al. (2022)

Regional asymmetry => hemispheric symmetry (CMIP5)



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Bender et al.
(2017), J Clim

Stockholm University

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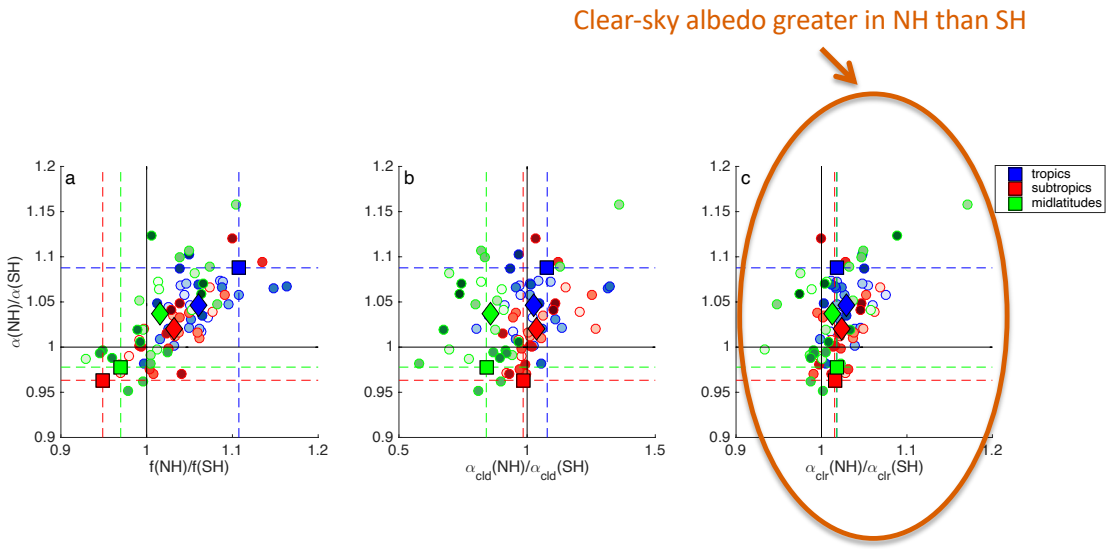
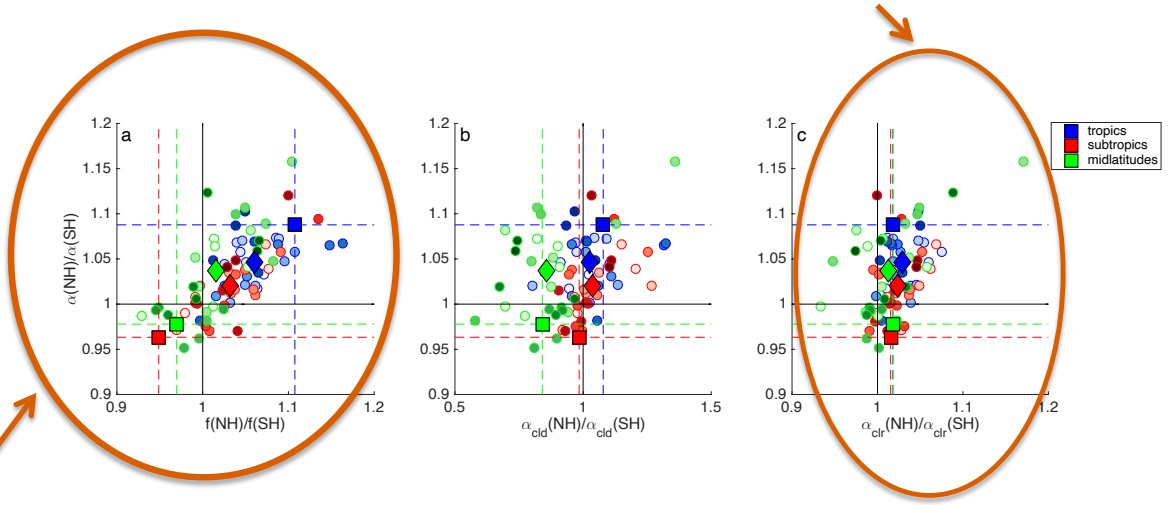


Bender et al. (2017), J Clim

Regional asymmetry => hemispheric symmetry (CMIP5)

Clear-sky albedo greater in NH than SH



Total albedo asymmetry follows cloud fraction asymmetry

Bender et al. (2017), J Clim

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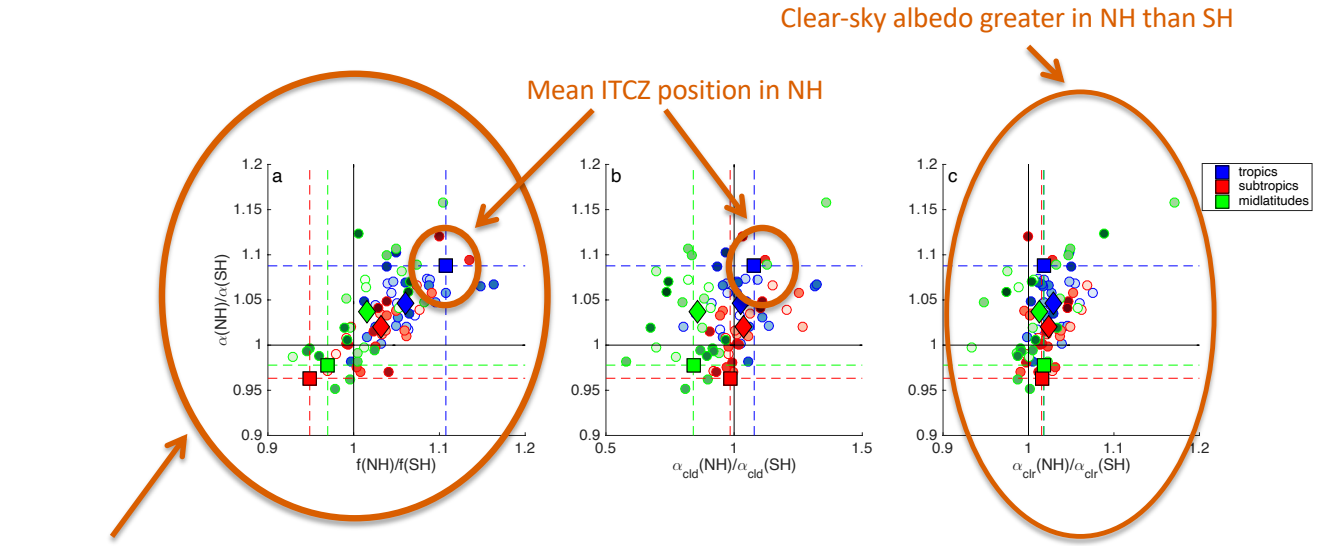

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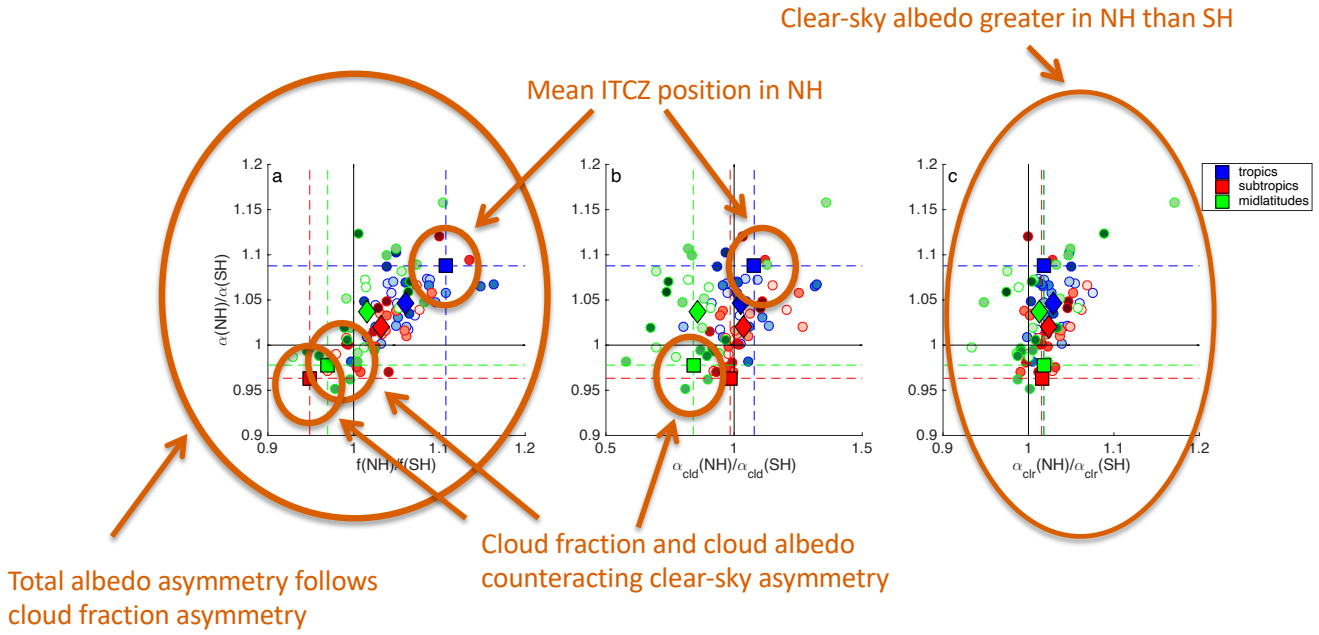

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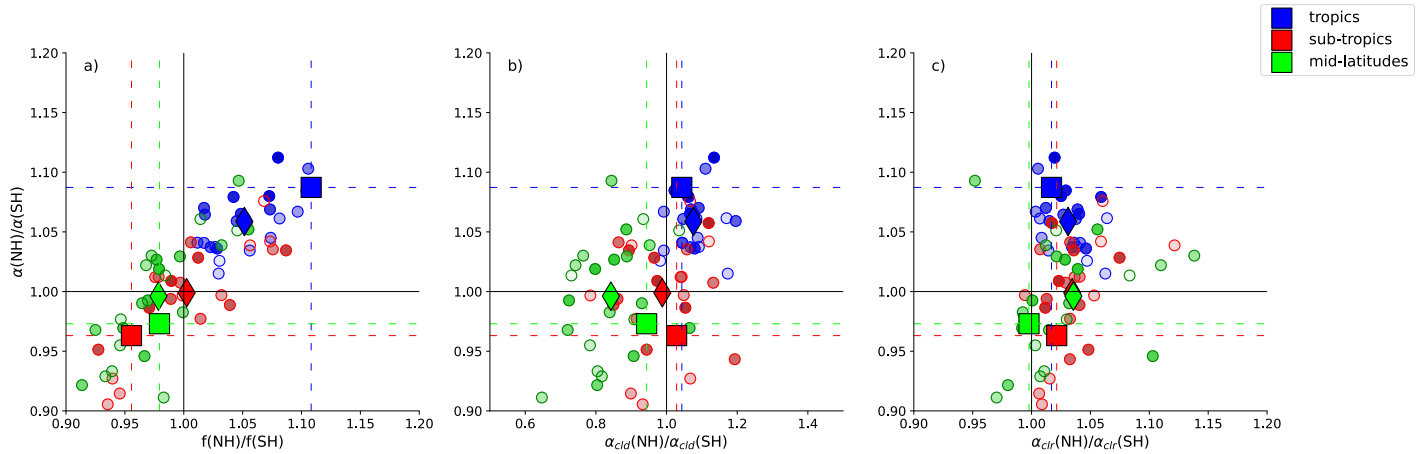
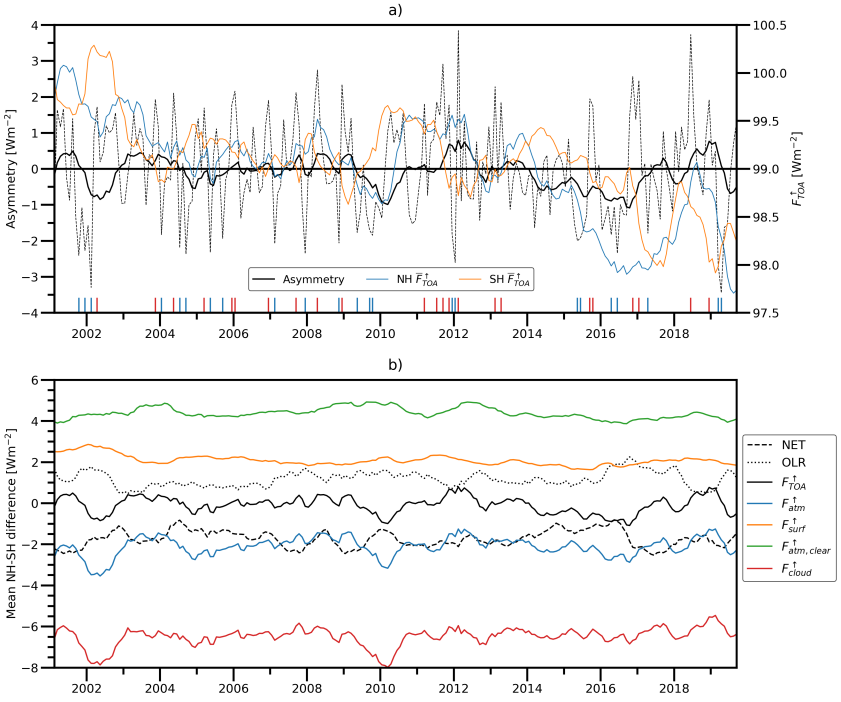


Courtesy Marcus Karlsson

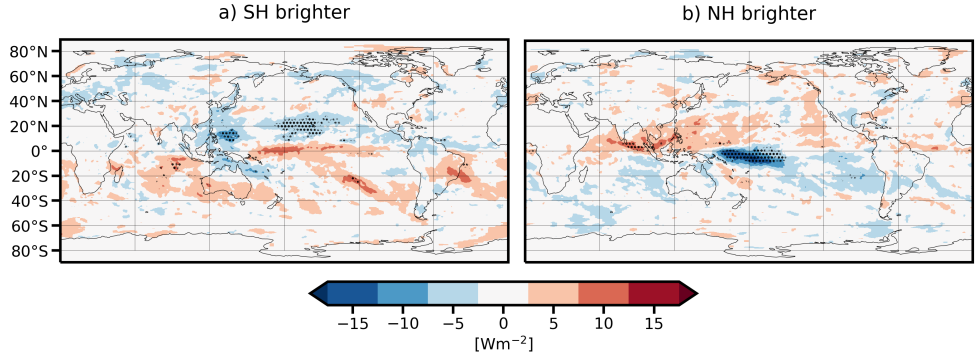
Albedo symmetry in CERES EBAF

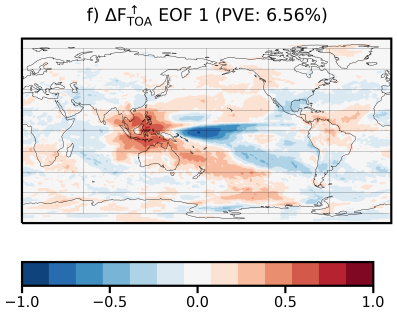
- Inter-hemispheric differences in reflected SW radiation within 0.1 Wm^{-2}
- Greater reflection from clouds in SH balances greater surface albedo and clear-sky albedo in NH



Jönsson and Bender (2021), J Clim

Patterns of anomalous asymmetry composites

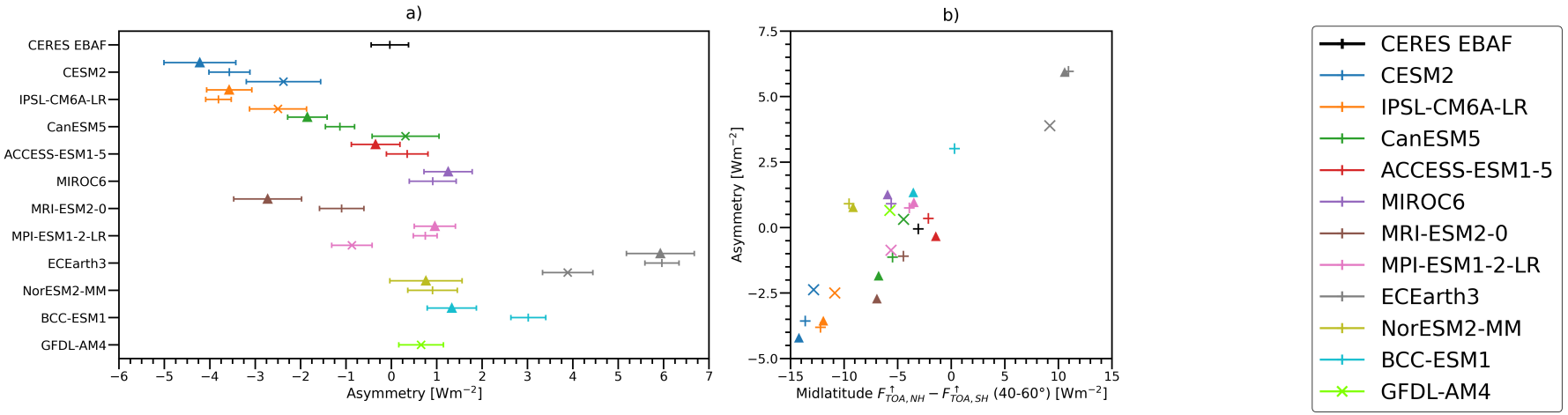




- The variability in asymmetry is strongly determined by tropical and subtropical clouds, particularly those related to non-neutral phases of ENSO.

Jönsson and Bender (2021), J Clim

Albedo symmetry in CMIP6 models

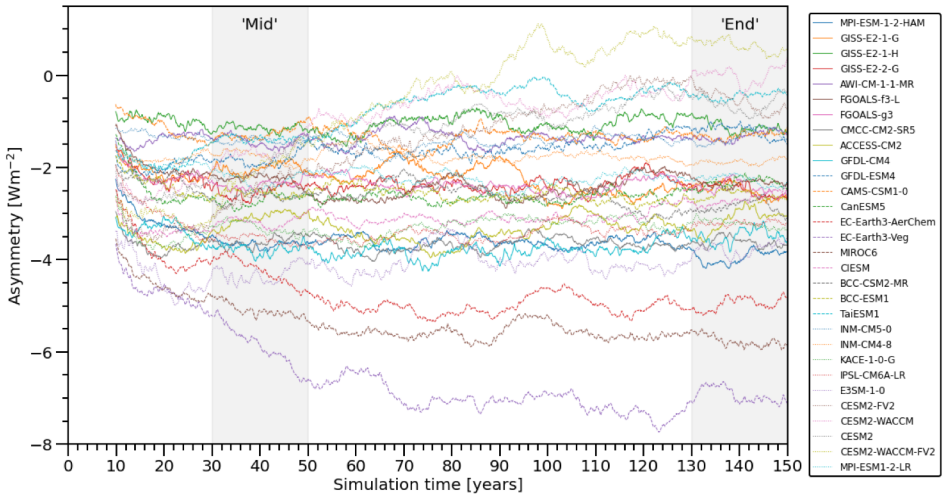


- CMIP6 models underestimate symmetry, and overestimate variability
- Fixed SST brings models closer to symmetry
- Model bias in symmetry driven by midlatitude clouds

Jönsson and Bender (2021), J Clim

Asymmetry response to strong forcing

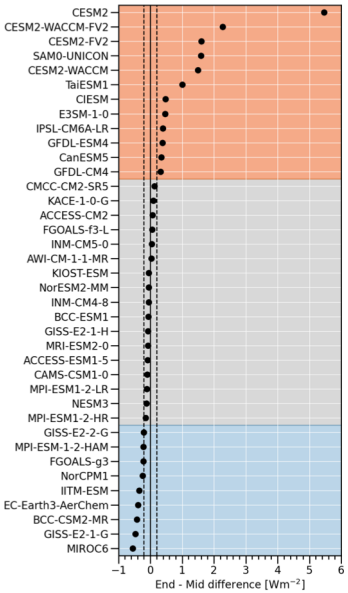
- Models lose NH sea ice in response to strong forcing
- Some models regain symmetry
- Restoration can be related to SH cloud loss, or to NH cloud gain - with different implications for cloud feedback



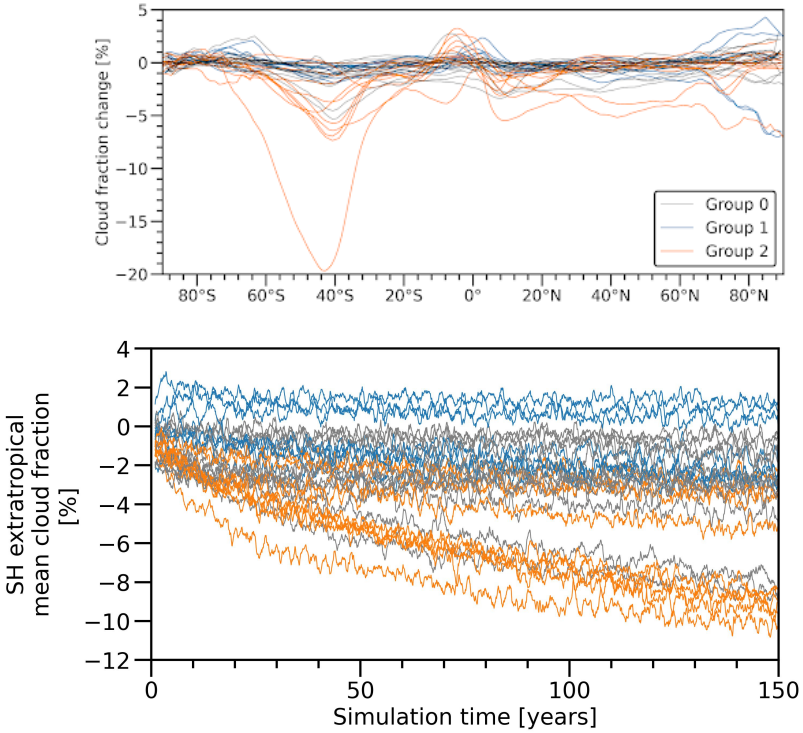
Courtesy Aiden Jönsson

Asymmetry response to strong forcing

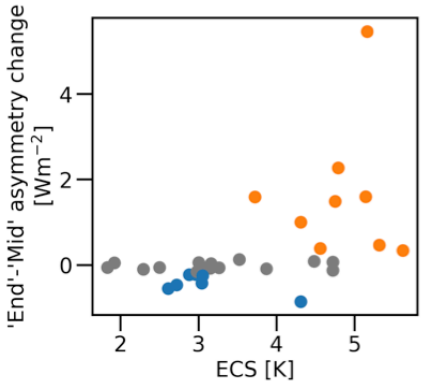
Models that restore more…



…lose more clouds in the SH mid-latitudes…

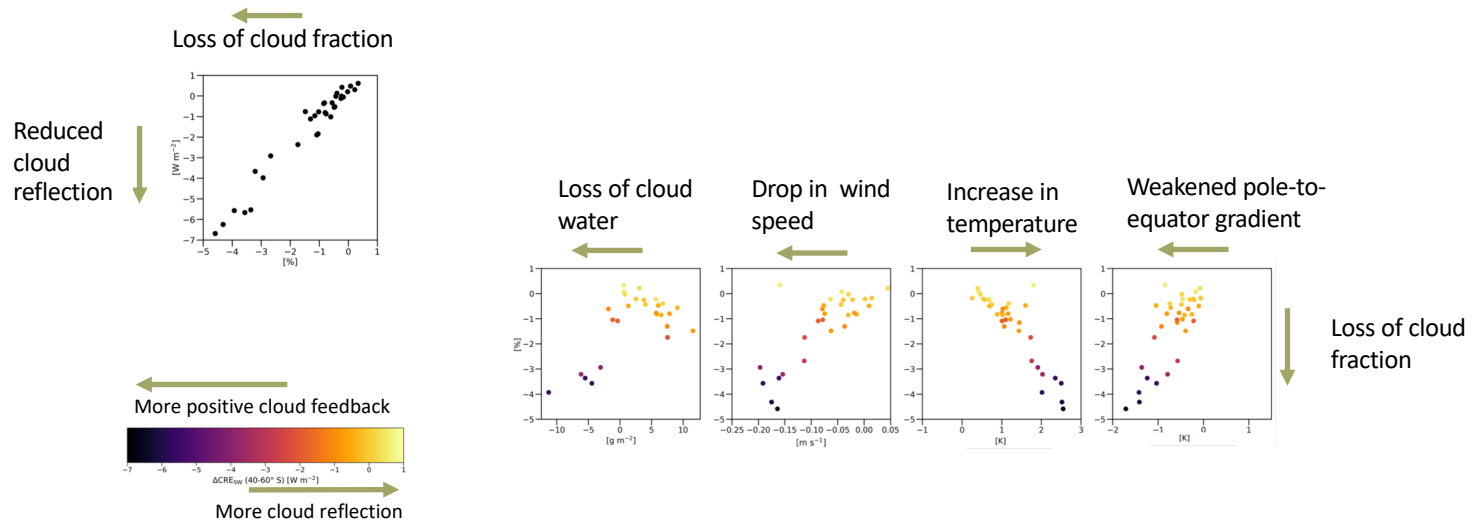


…and are typically at the high-ECS end



Courtesy Aiden Jönsson

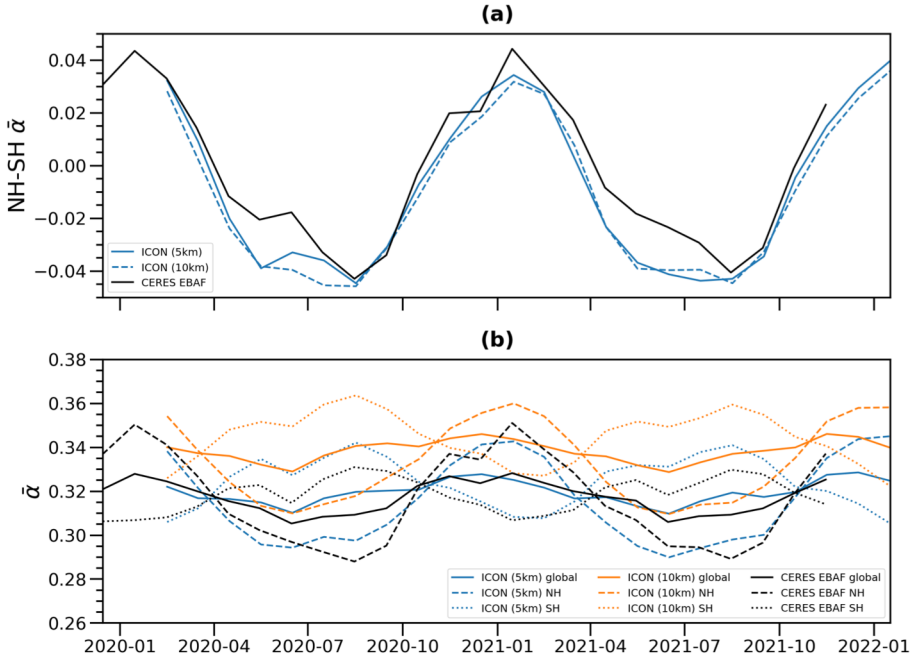
Factors controlling SH midlatitude cloud



- Models with greater drop in surface wind speed, more SST increase, more decrease in equator-to-pole gradient lose more cloud
- Similar cloud controlling factors determine present-day variability

Courtesy Aiden Jönsson

Albedo symmetry in storm resolving models

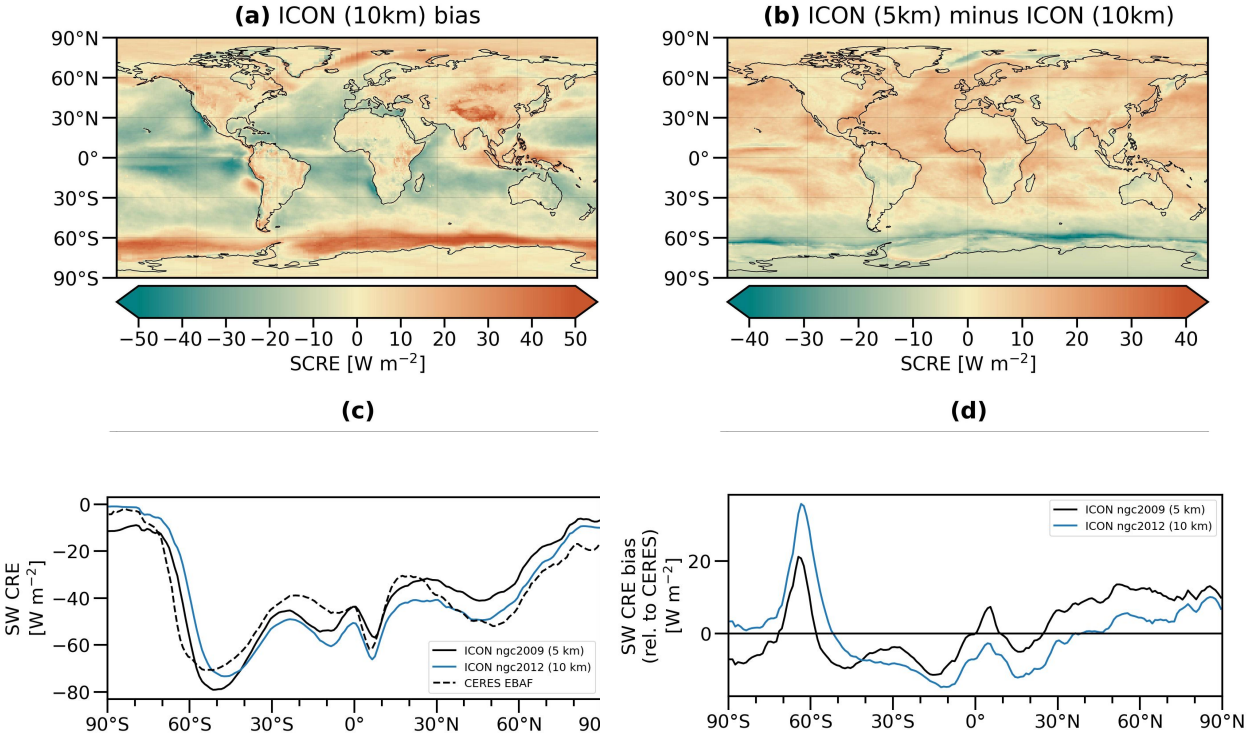


	NH-SH mean
ICON ngc2009 (5 km)	-0.89%
ICON ngc2012 (10 km)	-1.4%
CERES EBAF (clim)	-0.03%

- Storm-resolving (5km, 10km) ICON reproduces interhemispheric albedo symmetry well
- ICON (5km) represents absolute albedo well

Courtesy Aiden Jönsson

Albedo symmetry in storm resolving models



- Increasing resolution from 10 km to 5km reduces (the positive) CRE bias in SH midlatitude storm tracks
- Storm track position moves poleward with increasing resolution, in better agreement with CERES

Courtesy Aiden Jönsson

Summary

- Cloud-compensation of clear-sky asymmetry stems from mid-latitude cloud amount and cloud albedo, and subtropical cloud amount

- Midlatitude cloud properties are determining of level of symmetry, and model bias, while tropical cloud distribution determines its variability

- Restoration from CO_2-induced imbalance is driven by SH mid-latitude clouds. Most restoration seen in most sensitive models.

- Storm-resolving models show promise of improved representation of albedo symmetry

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